Tuning SOI filters with Liquid Crystals

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1. Introduction

The silicon-on-insulator (SOI) material system is today widely recognized as one of the most important platforms for the development of photonic components. This is mainly due to the fact that the mass fabrication techniques of the CMOS technology can be used for the fabrication of these SOI components.

However, using silicon for photonic components has significant downsides. For example, it is impossible to generate light efficiently in silicon because of the indirect band structure. Additionally, broad wavelength tuning is difficult to achieve in SOI components. These downsides can be overcome by integrating other materials in the SOI system. In recent years, III/V semiconductor materials have been integrated with SOI, allowing for light amplification, detection and even laser action in silicon components [1].

In this work, we investigate the possibility of using liquid crystal (LC) as a cladding material for SOI components. The huge electrooptic effect of LCs could lead to widely electrically tunable SOI components.

2. Simulations

Simulating structures that contain LC is far from trivial as it is necessary to take into account the full anisotropy of the LC. Many commercial tools are available for analyzing isotropic situations or situations with reduced anisotropy, but programs that can tackle a fully anisotropic problem are lacking.

We have developed a mode-solver based on finite elements that can analyze fully anisotropic waveguides. We use this tool together with a two-dimensional version of a program to calculate the liquid crystal orientation [2] to study the tuning possibilities of different SOI components.

The structure under investigation (see Fig 1 left) consists of a 1 µm SiO_2 substrate, a rectangular cross-section Si waveguide and a cladding layer of E7 (an LC mixture with a 0.2 optical anisotropy). Planar alignment of the LC along the axis of propagation of the waveguide is used and electrodes are placed below the oxide and above the LC layer. Commonly used dimensions for this kind of waveguide are a width of 500nm and a height of 220nm. In our simulations, we calculate the effective index of the guided mode in the waveguide for different values of the applied voltage. We also study the influence of the width and height of the waveguide.

The calculations clearly show changes in the effective index of about 0.3%. From this we can deduce the changes in the characteristics of photonic components like ring resonators and Mach-Zehnder interferometers (MZI). For ring resonators (see Fig 1 right) we find a tunability of up to 5 nm for a voltage up to 15 V. For MZIs the tunability is related to the waveguide length.

3. Experiments

We fabricated structures consisting of an SOI ring resonator with a top layer of liquid crystal (E7). The LC is sandwiched between the SOI chip and an ITO coated glass plate. The cell gap is maintained by two stripes of spacer containing glue at the left and right sides. Early experiments show a tuning range of a few nanometers with applied voltages up to 12V. Further tests with ring resonators and MZIs are underway. We are also working towards structures with a far greater tunability by influencing the confinement of the light locally.

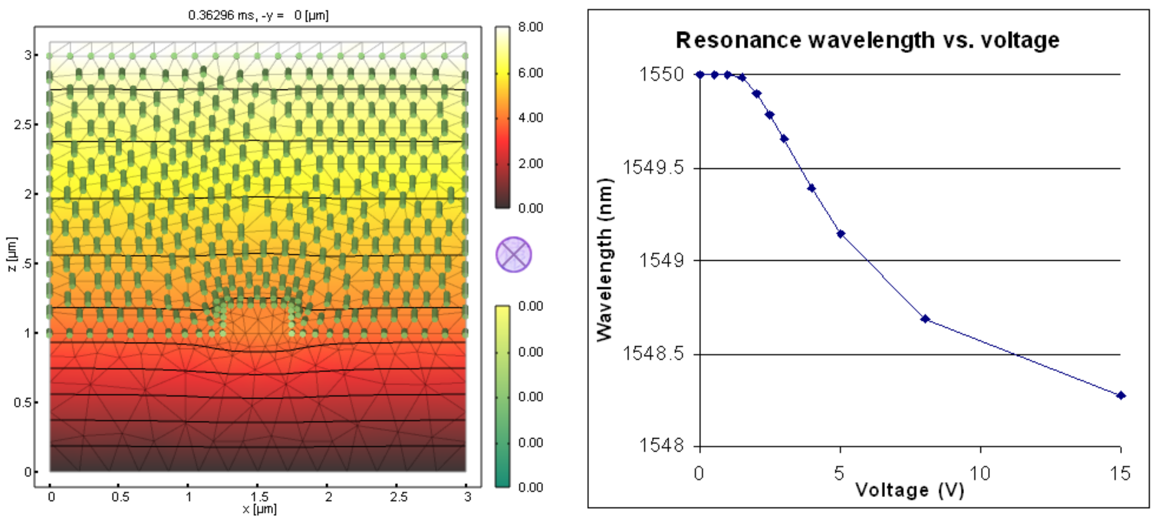

Fig 1: *left*: SOI waveguide with LC cladding (8V applied voltage) showing local director orientation and biasing potential contour lines. *right*: simulated tuning of an SOI ring resonator.

4. References

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